

## ROBOTICS RESEARCH AT CANADIAN SPACE AGENCY

**Raymond Hui**

Directorate of Space Mechanics

Canadian Space Agency

6767 route de l'Aéroport

Saint-Hubert Québec

Canada J3Y 8Y9

Tel: (514) 926-4679 Fax: (514) 926-4695

email: [huir@sp-agency.ca](mailto:huir@sp-agency.ca)

### KEY WORDS AND PHRASES

Canadian Space Agency, robotics research, technology spin-off.

### ABSTRACT

*In addition to major crown projects such as the Mobile Servicing System for Space Station, the Canadian Space Agency is also engaged in internal, industrial and academic research and development activities in robotics and other space-related areas of science and technology. These activities support current and future space projects, and lead to technology development which can be spun off to terrestrial applications, thus satisfying the Agency's objective of providing economic benefits to the public at large through its space-related work.*

### INTRODUCTION

The Canadian Space Agency (CSA) was formally established on in 1989 to bring to a central organization the responsibilities of coordinating and managing the Canadian Space Program. Our formal mandate is to (i) promote the peaceful use and development of space, (ii) advance the knowledge of space through science, and (iii) ensure that space science and technology provide social and economic benefits for Canadians. In the fall

of 1993, most of the constituent groups of CSA (previously distributed in a number of locations in Ottawa, Ontario) and carrying out this mandate were moved to a central location in St-Hubert, Québec.

In the recently finalized Canadian Long Term Space Plan [9], the objectives and action plan for the Canadian Space Program in the next ten years are described. It is clear from this plan that in addition to major crown projects such as Radarsat and Mobile Servicing System (MSS) for Space Station, the Canadian Space Agency will continue to engage in research and development activities under the auspices of its Space Science and Space Technology Branches, as well as the Canadian Astronaut Program. Herein, the discussion is focused on R & D in robotics at CSA. This subject has been previously discussed in [3, 4]. More updated information is provided here.

### ROBOTICS RESEARCH

The Strategic Technologies for Automation and Robotics (STEAR) program was established to complement the work on MSS and to promote Canadian robotics activities. Specifically, companies, universities and research organizations across Canada are given contracts to develop technologies for the MSS evolution and terrestrial spinoff applications.

To date, contracts for eight different STEAR projects have been awarded. The areas of technology being investigated are (i) automation of operations and expert systems, (ii) health and automated power management, (iii) autonomous robotics, (iv) enhanced space vision systems, (v) trajectory planning and obstacle avoidance, (vi) protection of materials in the space environment, (vii) tactile and proximity sensors, and (viii) MSS ground control.

The Canadian Astronaut Program (CAP) pursues R & D activities which will be tested and/or implemented by Canadian astronauts in future space flight missions. One such example is the Space Vision System (SVS) [11]. Current projects which are being considered for future flights include a motion isolation mount based on magnetic levitation [13] and human machine interface based on speech recognition [12].

The Space Technology Branch at CSA has a dual mandate to develop necessary space technologies to support current and future missions as well as to develop and transfer terrestrial technology spin-offs to the industry. In the area of robotics, there is ongoing R & D in the areas of teleoperation, sensor fusion, development of advanced control techniques, control of flexible manipulators, free flyers, human-machine interface and robot calibration in space. These activities include theoretical and experimental work and are described in detail below.

Successful testing of the SVS on mission STS-52 [11] showed that it was possible to calibrate robot performance in space using photogrammetry techniques. The REACH project [8] is aimed at evaluating and characterizing the Space Station Remote Manipulator System (SSRMS) in orbit. Parameters such as accuracy, repeatability, stopping distance, etc. will be measured. A

ground test-bed is being constructed to verify the validity of the characterization procedure. The concept of REACH may be tested in an upcoming Shuttle flight using the Shuttle Remote Manipulator System (SRMS) with the SSRMS to be characterized after evaluating the initial flight data. Other experiments involving calibration of the SRMS and the Shuttle are being contemplated as an operational version of SVS will become available on future Shuttle missions.

Since it will be difficult and expensive to alter the hardware of MSS once it is set up in space, a natural area to incorporate new technology is remote control. To this end, CSA researchers are examining issues such as bilateral teleoperation and effects of communications delay. Novel hand controllers and haptic interface devices have been invented as a result of this work [7].

To facilitate experiments involving multiple devices such as hand controllers and robots, a general host environment dubbed *Ghost* is being developed to enable non-expert users to link up devices and processes across a network to form customized experimental systems [6]. Currently, the available devices include a 7-dof robot, a Polhemus sensor connected to the CSA network via a PC running QNX and a UNIX workstation respectively. The processes which can be executed include two types of simulated robots, a driver which allows a computer mouse to be used like a hand controller, and various display processes. Other robots including the above-mentioned force-reflecting mechanisms and a planar free flyer as well as processes such as simulation programs will be added. In the near future, it will be possible to communicate with and control devices at sites outside CSA.

Dynamics and control of flexible manipulators are a natural problem for CSA

to study because Canada has contributed and is contributing large, flexible robotic manipulators to the Shuttle and Space Station programs respectively. The incorporation of intelligent control methods such as fuzzy control, neural networks and genetic algorithms [10, 16], as well as the use of smart structures is being examined. Another area of interest is force control of manipulators with flexible links and/or joints [15]. Experiments with direct-drive motors and a flexible link, as well as with flexible joints (harmonic drives) are being conducted. The dynamic coupling between the Special Purpose Dextrous Manipulator (SPDM) and the SSRMS is also a subject of interest being studied in collaboration with Laval University [14].

Space servicing is potentially a viable commercialization opportunity in space in the near future. Although it is not part of the Long Term Space Plan, it is important to understand the dynamics and control of servicers and servicing manipulators [5]. To this end, a planar test bed based on air bearings has been designed at CSA [2]. Ongoing research on the dynamics of space manipulators is leading to the development of a new philosophy on their design.

## TECHNOLOGY SPIN-OFF

One mandate of CSA and the Space Technology Branch is the transfer of technology to the industrial sector. The STEAR program mentioned above is the main channel through which MSS technology can be spun off for terrestrial applications. The approach taken in developing the spin-off technology is somewhat unique. STEAR contracts have been and will be given out to companies other than the prime contractors responsible for the design, construction and delivery of MSS. The objectives of these contracts are to develop technology which

may be used in evolutionary MSS in parallel with but independently of the prime contractors as well as terrestrial applications.

In addition to STEAR which is a program to direct, fund and coordinate industrial R & D, internal research at CSA, in particular the robotics has led to technology which can be spun off into commercial products for terrestrial applications. The hand controller mechanisms and *Ghost* mentioned above are examples of research results which have great commercialization potential.

## CONCLUSIONS

CSA is engaged in various research and development activities in addition to major crown projects. In the area of robotics, the focus is on characterization of robots in space, remote manipulation, human-machine interface, flexible manipulators and space servicing. Research in these areas support the major projects as well as lead to technology spin-offs which provide socio-economic benefits for Canada.

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